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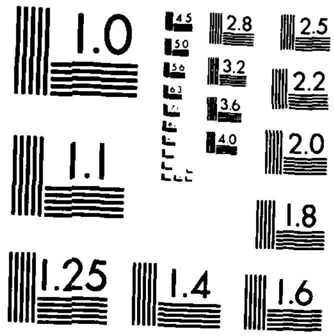

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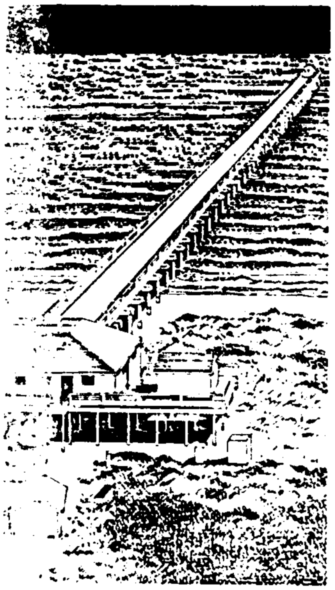

WAVE INFORMATION STUDIES OF US COASTLINES

WIS REPORT 15

ATLANTIC COAST HINDCAST, PHASE II WAVE INFORMATION: ADDITIONAL EXTREMAL ESTIMATES

by

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May 1985

Final Report

Approved For Public Release; Distribution Unlimited

Prepared for

DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER WIS Report 15	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (*and Subtitle*) ATLANTIC COAST HINDCAST, PHASE II WAVE INFORMATION: ADDITIONAL EXTREMAL ESTIMATES	5. TYPE OF REPORT & PERIOD COVERED Final report
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) William D. Corson Barbara A. Tracy	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Engineer Waterways Experiment Station Coastal Engineering Research Center PO Box 631, Vicksburg, Mississippi 39180-0631	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS DEPARTMENT OF THE ARMY US Army Corps of Engineers Washington, DC 20314-1000	12. REPORT DATE May 1985 13. NUMBER OF PAGES 36
14. MONITORING AGENCY NAME & ADDRESS(*if different from Controlling Office*)	15. SECURITY CLASS. (*of this report*) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

Ocean Waves--Atlantic Ocean, (LC)
Storm Surges--Atlantic Coast (United States) (LC)

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

Estimates of extreme wave heights for 73 open-ocean locations on the US East Coast are presented. The estimates include the median wave heights and interquartile ranges for 100-, 50-, 20-, 10-, and 5-year return periods. Only waves generated by extra-tropical storms are considered. Hurricane-generated waves will be analyzed in future work.

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PREFACE

In late 1976 a study to produce a wave climate for US coastal waters was initiated at the US Army Engineer Waterways Experiment Station (WES). The Wave Information Study (WIS) was authorized by the Office, Chief of Engineers (OCE), as a part of the Coastal Field Data Collection Program which is managed by the Coastal Engineering Research Center (CERC) at WES.

This report, the fifteenth in a series, presents additional extremal estimates for the Atlantic WIS Phase II wave data. It was prepared by Mr. W. D. Corson and Mrs. B. A. Tracy with assistance from other members of the WIS staff which include: Dr. C. E. Abel, Mrs. R. M. Brooks, Mr. P. D. Farrar, Miss B. J. Groves, Dr. R. E. Jensen, Mrs. J. B. Payne, and Mrs. D. S. Ragsdale.

The study was conducted at CERC under the direction of Dr. R. W. Whalin, Chief, CERC, Mr. C. E. Chatham, Jr., Chief, Wave Dynamics Division, and Mr. D. G. Outlaw, Chief, Wave Processes Branch. Mr. J. H. Lockhart, Jr., OCE, was Technical Monitor for the Coastal Field Data Collection Program.

Commander and Director of WES during the publication of this report was COL Robert C. Lee, CE. Technical Director was Mr. Fred R. Brown.

A-1

CONTENTS

ATLANTIC COAST HINDCAST, PHASE II WAVE INFORMATION: ADDITIONAL EXTREMAL ESTIMATES

PART I: INTRODUCTION

1. Appendixes A-II of Corson, et al. (1982) presented summaries of Atlantic Coast Wave Information Study (ACWIS) hindcast wave information for 33 open-ocean locations off the US East Coast. The 33 locations, which are called stations in Wave Information Study (WIS) reports, are only a portion of the 73 stations for which wave data* were processed. In this report's appendixes, revised extremal analyses are presented for all 73 of the ACWIS Phase II stations (Figure 1, Table 1). Only waves generated by extra-tropical storms are considered. Hurricane-generated waves will be added to the data base in the near future.

2. The extremal analyses were revised in two ways. First, the 20-year (1956-1975) ACWIS Phase II wave height data were reanalyzed using a technique which provides more information on the extremal estimates than the return period diagrams in Appendixes A through GG of Corson, et al. (1982)(Appendix A). In addition to an improved extremal analysis technique for the 20 years of hindcast data, the 20-year data base was extended to 54 years by hindcasting 12 severe storms which occurred within 1922 through 1955 (Appendix B). In the following sections of this report, as in Corson, et al. (1982), a brief description of the return period tables is given, and some discussion on the use of the tables, including examples, is provided.

* Surface pressure and wind data also were archived as part of WIS (Brooks and Corson 1984).

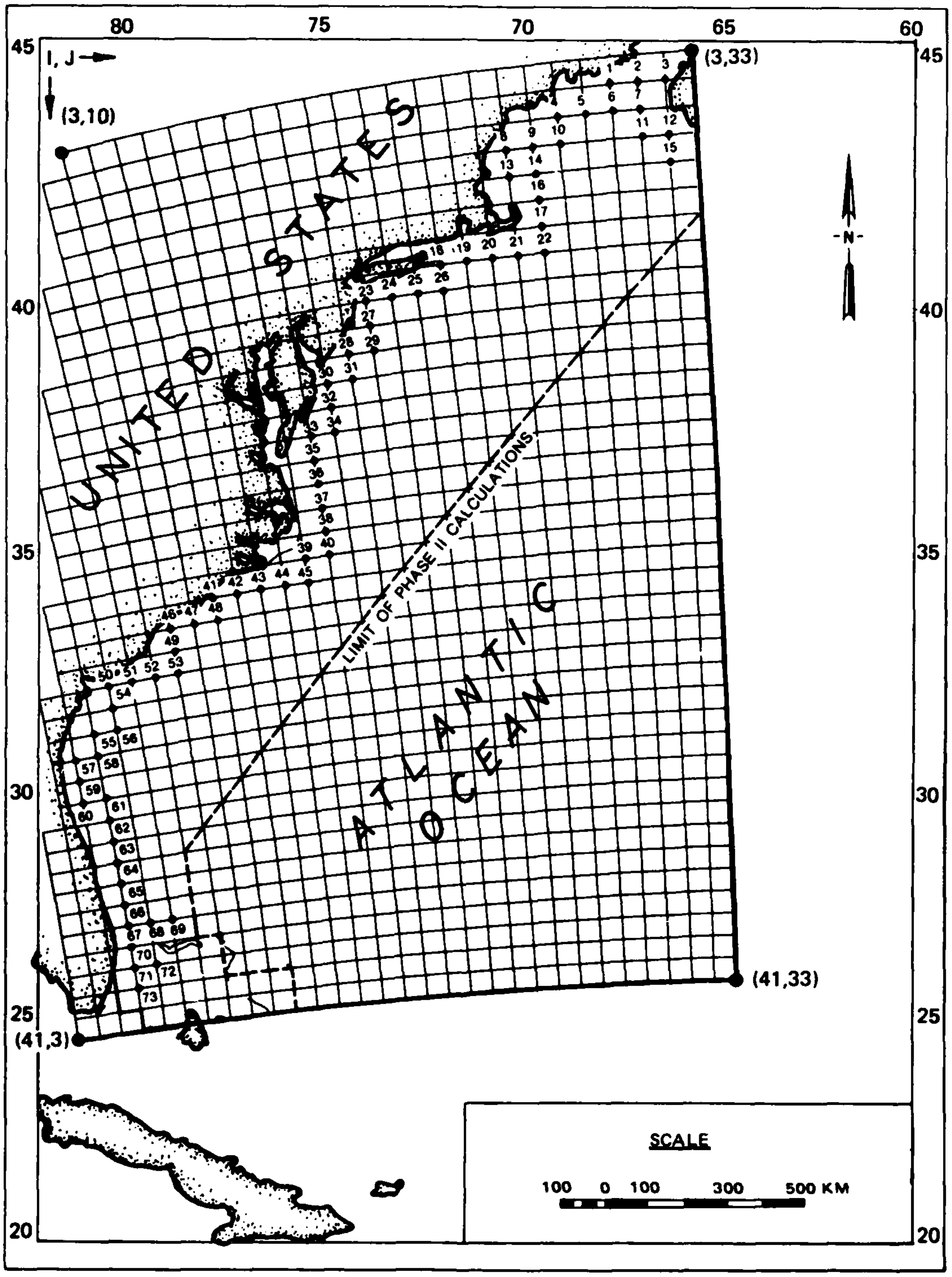

Figure 1. Atlantic Phase II spherical orthogonal grid showing the East Coast of the US and the Atlantic Ocean. (Numbered points indicate sites for which wave data were processed; latitude is shown on the vertical border and longitude is shown on the upper horizontal border.)

Table 1

ACWIS Phase II Station

Station Number	Latitude deg N	Longitude deg W	Station Number	Latitude deg N	Longitude deg W
1	44.24	67.71	46	33.55	78.72
2	44.28	67.02	47	33.64	78.13
3	44.32	66.32	48	33.73	77.54
4	43.64	69.02	49	33.08	78.62
5	43.69	68.33	50	32.33	80.26
6	43.74	67.65	51	32.42	79.68
7	43.79	66.96	52	32.51	79.10
8	43.03	70.31	53	32.60	78.51
9	43.09	69.63	54	31.86	80.15
10	43.15	68.95	55	31.29	80.62
11	43.29	66.90	56	31.39	80.01
12	43.33	66.21	57	30.73	81.08
13	42.54	70.23	58	30.82	80.51
14	42.60	69.55	59	30.26	80.98
15	42.83	66.16	60	29.79	80.88
16	42.11	69.48	61	29.89	80.31
17	41.61	69.40	62	29.42	80.21
18	40.88	71.96	63	28.95	80.11
19	40.94	71.30	64	28.48	80.02
20	41.01	70.65	65	28.01	79.93
21	41.06	69.99	66	27.54	79.84
22	42.12	69.33	67	27.07	79.75
23	40.17	73.82	68	27.15	79.20
24	40.24	73.17	69	27.23	78.64
25	40.32	72.52	70	26.60	79.67
26	40.39	71.87	71	26.13	79.58
27	39.68	73.72	72	26.20	79.03
28	39.12	74.26	73	25.66	79.50
29	39.20	73.62			
30	38.55	74.79			
31	38.63	74.16			
32	38.07	74.69			
33	37.51	75.21			
34	37.59	74.59			
35	37.03	75.11			
36	36.54	75.02			
37	36.06	74.92			
38	35.58	74.83			
39	35.02	75.34			
40	35.09	74.74			
41	34.12	77.64			
42	34.29	77.04			
43	34.38	76.45			
44	34.46	75.85			
45	34.54	75.25			

PART II: RETURN PERIOD TABLE DERIVED FROM 20-YEAR DATA BASE

Description

3. The 20 years of ACWIS Phase II wave data provide an excellent data base for use in extremal wave statistics. The distribution of extreme wave heights in the ACWIS Phase II data was analyzed to produce an estimate of the median 50-year wave height at each Phase II station. The interquartile range for the median 50-year wave height was calculated also. Calculations using the same distribution were done to produce the median wave heights and their respective interquartile ranges (Appendix A) for the 20-, 10-, and 5-year return periods.

4. The first step in producing a probability distribution from the 20 years of data is to sort the wave data at each station by significant height H_s beginning with the largest. The sorted data sets were read into a computer program which recorded only one extreme wave per storm (a storm was considered to be a maximum of 5 days long) to be used in the extremal calculations. A maximum of 25 storm waves was considered to be the station's extreme waves, but no extreme waves under 4.0m were used. The extreme waves were ranked using the technique described in Borgman and Resio (1977) and Isaacson and MacKenzie (1981). The ranking procedure assigns a probability of $k/n+1$ to an extreme wave (k is the rank of the wave with $k = n$ for the highest wave). This probability corresponds to the probability that the random wave height variable is less than or equal to the wave height with rank $= k$.

5. A functional form of this probability function that produces a straight line when plotted against the wave heights is necessary to make extrapolations beyond the data set. The function

$$F_X(x) = e^{-e^{-(ax+b)}} \tag{1}$$

was used, where x is one of the k wave heights being represented by the probability, $F_X(x)$, and a and b are constants depending on the data set. Evaluating this equation into a more usable form gives

$$-\ln[-\ln F_X(x)] = ax+b \tag{2}$$

6. A plot of $-\ln[\ln F_{\chi}(x)]$ versus x, the wave height, should yield a straight line with slope, a, and intercept, b. The actual calculations were done using the form

$$\ln(x) = m \{-\ln[-\ln F_{\chi}(x)]\} + B \tag{3}$$

where

x = wave height

$\ln(x)$ = natural log of the wave height

m = slope

B = ordinate intercept

A least-squares fit was applied to the data to find the slope and intercept of the straight line calculated from the H_s data. It was assumed that the extreme wave heights x_1, x_2, $\ldots x_n$ (n = number of data points) were a sequence of random variables and that χ_{max} was the maximum for the sequence. If all the random variables in the sequence have the same distribution function, then,

$$F_{\chi_{max}}(x) = [F_{\chi}(x)]^n \tag{4}$$

7. In order to extrapolate to a 50-year wave height, the n value in Equation 4 is multiplied by 2.5, and $F_{\chi}(x)$, the probability fractile for the median 50-year wave height, can be calculated by

$$(0.5)^{\frac{1}{2.5n}} = F_{\chi}(x) \tag{5}$$

where 0.5 (the median) has been substituted for $F_{\chi_{max}}(x)$ and n is the number of data points in the 20-year hindcast wave extrema. This value of $(0.5)^{\frac{1}{2.5n}}$ corresponds to an extreme wave height. To find this extreme wave height it is necessary to transform this $F_{\chi}(x)$ to an abscissa value using

$$-\ln \left\{ -\ln \left[(0.5)^{\frac{1}{2.5n}} \right] \right\} \quad (6)$$

The corresponding ordinate value (using Equation 3) is the ln (natural log) of the extreme wave height. The interquartile range for the 0.25 and 0.75 fractiles can be calculated in the same way to give a range of extreme wave heights. These values were calculated using Equation 3 to determine the ordinates for the following two abscissas:

$$-\ln \left\{ -\ln \left[(0.25)^{\frac{1}{2.5n}} \right] \right\} \quad (7)$$

and

$$-\ln \left\{ -\ln \left[(0.75)^{\frac{1}{2.5n}} \right] \right\} \quad (8)$$

8. The extrapolated wave heights are affected by the assumed initial probability distribution and by the data points themselves. It is important to view the interquartile range rather than only the extrapolated median wave height.

9. The medians for the 20-, 10-, and 5-year extreme wave heights were calculated using an approximation for the return period. The familiar formula for return period (Issacson and MacKenzie 1981) is

$$T_R = r \left[\frac{1}{1 - P(H)} \right] \quad (9).$$

where T_R is the return period in years, r is average time between storms, and $P(H)$ (which corresponds to the probability that the random wave height is less than or equal to the wave height with rank equal to K (see paragraph 4)) is the initial probability distribution $F_\chi(x)$ of the extreme wave heights. Obviously, $1 - P(H)$ is the probability of encountering a wave greater than a wave with rank = K. This can be approximated by

$$\frac{T_R}{r} \cong \frac{1}{2} + \exp\,(y) \quad (10)$$

where

$$y = -\ln\{-\ln[P(H)]\} \tag{11}$$

and

$$\frac{T_R}{r} > 7 \text{ (Isaacson and MacKenzie 1981)} \tag{12}$$

To gain some feeling for the numbers involved, note that the numerical values of y, the reduced probability function (see abscissa in Figure 2), are typically greater than 1.8 for the larger recorded wave heights.

10. The interquartile ranges for the 20-, 10-, and 5-year wave heights were calculated using the same process as the range for the extrapolated median 50-year wave height. In the case of the 20-year wave height, the 0.25 quartile wave height was calculated by finding the ordinate corresponding to the abscissa

$$-\ln\left\{-\ln\left[(0.25)^{\frac{1}{n}}\right]\right\} \tag{13}$$

where n equals number of data points in the 20-year hindcast wave extrema. The 10-year 0.25 quartile was found by calculating the abscissa as follows:

$$-\ln\left\{-\ln\left[(0.25)^{\frac{1}{n/2}}\right]\right\} \tag{14}$$

The 5-year ranges used an exponent of $1/(n/4)$.

11. Considering that the extremal estimates were derived from an assumed probability distribution function, the reader should realize that all the large wave heights will not plot on a least-squares-fit line drawn through a distribution of those wave heights. Figure 2 indicates the typical variation between the data points and the least-squares line. It is obvious from Figure 2 that the least-squares fit was not applied using the lowest data points. The line's slope and intercept were calculated using all data above the 1-year return period calculated from all the data using Equation 9. This excludes storms that may be from a population other than severe storms. The interquartile ranges are shaded around the 20- and 50-year wave heights. The shaded regions in Figure 2 contain all the wave heights that fall between the

ATLANTIC PHASE 2 STATION 36 (36.54N, 75.02W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	10.8	12.1	9.8
20	9.0	10.7	8.6
10	8.2	9.7	7.9
5	7.4	8.9	7.2

ATLANTIC PHASE 2 STATION 37 (36.06N, 74.92W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	12.0	13.8	10.8
20	9.9	12.0	9.4
10	8.8	10.8	8.5
5	7.9	9.7	7.6

ATLANTIC PHASE 2 STATION 38 (35.58N, 74.83W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	13.5	15.7	12.0
20	10.8	13.4	10.2
10	9.5	11.9	9.1
5	8.4	10.6	8.0

ATLANTIC PHASE 2 STATION 39 (35.02N, 75.34W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	10.8	12.3	9.8
20	9.0	10.8	8.5
10	8.1	9.7	7.7
5	7.3	8.8	7.0

ATLANTIC PHASE 2 STATION 40 (35.09N, 74.74W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	13.9	16.3	12.3
20	11.1	13.9	10.5
10	9.8	12.3	9.3
5	8.6	10.8	8.2

ATLANTIC PHASE 2 STATION 41 (34.12N, 77.64W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.3	7.9	6.8
20	6.5	7.2	6.2
10	6.1	6.8	5.8
5	5.6	6.3	5.4

ATLANTIC PHASE 2 STATION 42 (34.29N, 77.04W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	8.1	8.8	7.6
20	7.2	8.1	7.0
10	6.8	7.6	6.5
5	6.3	7.1	6.1

ATLANTIC PHASE 2 STATION 29 (39.20N, 73.62W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	9.1	9.9	8.5
20	8.0	9.0	7.8
10	7.5	8.5	7.3
5	7.0	7.9	6.8

ATLANTIC PHASE 2 STATION 30 (38.55N, 74.79W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.9	8.5	7.4
20	7.0	7.9	6.8
10	6.6	7.4	6.4
5	6.2	7.0	6.0

ATLANTIC PHASE 2 STATION 31 (38.63N, 74.16W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	8.9	9.7	8.3
20	7.9	8.9	7.6
10	7.4	8.3	7.2
5	6.9	7.8	6.7

ATLANTIC PHASE 2 STATION 32 (38.07N, 74.69W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	9.5	10.5	8.7
20	8.2	9.4	7.9
10	7.5	8.7	7.3
5	6.9	8.0	6.7

ATLANTIC PHASE 2 STATION 33 (37.51N, 75.21W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	9.9	11.2	8.9
20	8.2	9.8	7.8
10	7.4	8.9	7.1
5	6.6	8.0	6.4

ATLANTIC PHASE 2 STATION 34 (37.59N, 74.59W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	10.1	11.3	9.3
20	8.6	10.1	8.3
10	7.9	9.3	7.6
5	7.2	8.5	7.0

ATLANTIC PHASE 2 STATION 35 (37.03N, 75.11W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	10.0	11.2	9.2
20	8.5	10.0	8.1
10	7.7	9.1	7.4
5	7.0	8.3	6.8

ATLANTIC PHASE 2 STATION 22 (42.12N, 69.33W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	11.8	13.1	10.9
20	10.2	11.8	9.8
10	9.4	10.9	9.1
5	8.6	10.0	8.4

ATLANTIC PHASE 2 STATION 23 (40.17N, 73.82W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	9.2	10.5	8.3
20	7.8	9.1	7.2
10	7.0	8.2	6.5
5	6.3	7.4	5.8

ATLANTIC PHASE 2 STATION 24 (40.24N, 73.17W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	9.1	10.1	8.5
20	7.9	9.1	7.6
10	7.3	8.4	7.1
5	6.7	7.8	6.5

ATLANTIC PHASE 2 STATION 25 (40.32N, 72.52W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	9.8	10.9	9.1
20	8.5	9.8	8.1
10	7.8	9.0	7.5
5	7.2	8.3	6.9

ATLANTIC PHASE 2 STATION 26 (40.39N, 71.87W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	10.5	11.6	9.6
20	9.0	10.4	8.7
10	8.3	9.6	8.0
5	7.6	8.9	7.4

ATLANTIC PHASE 2 STATION 27 (39.68N, 73.72W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	8.6	9.5	8.0
20	7.5	8.6	7.3
10	6.9	8.0	6.7
5	6.4	7.4	6.2

ATLANTIC PHASE 2 STATION 28 (39.12N, 74.26W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	8.1	8.8	7.7
20	7.3	8.1	7.1
10	6.8	7.6	6.6
5	6.4	7.2	6.2

ATLANTIC PHASE 2 STATION 15 (42.83N, 66.16W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	12.3	13.7	11.3
20	10.6	12.2	10.1
10	9.7	11.2	9.3
5	8.8	10.3	8.5

ATLANTIC PHASE 2 STATION 16 (42.11N, 69.48W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	10.9	12.3	9.9
20	9.2	10.9	8.8
10	8.3	9.9	8.0
5	7.6	9.0	7.3

ATLANTIC PHASE 2 STATION 17 (41.61N, 69.40W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	11.2	12.4	10.3
20	9.6	11.1	9.2
10	8.8	10.2	8.5
5	8.1	9.4	7.8

ATLANTIC PHASE 2 STATION 18 (40.88N, 71.96W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	10.1	11.4	9.1
20	8.4	10.0	8.0
10	7.6	9.1	7.3
5	6.8	8.2	6.6

ATLANTIC PHASE 2 STATION 19 (40.94N, 71.30W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	11.0	12.4	10.0
20	9.3	10.9	8.9
10	8.4	10.0	8.1
5	7.7	9.1	7.4

ATLANTIC PHASE 2 STATION 20 (41.01N, 70.65W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	11.3	12.6	10.4
20	9.6	11.3	9.3
10	8.8	10.3	8.5
5	8.0	9.5	7.8

ATLANTIC PHASE 2 STATION 21 (41.06N, 69.99W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	12.0	13.4	11.0
20	10.2	11.9	9.7
10	9.3	10.9	8.9
5	8.4	10.0	8.1

ATLANTIC PHASE 2 STATION 8 (43.03N, 70.31W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	8.0	8.7	7.5
20	7.1	8.0	6.9
10	6.6	7.4	6.4
5	6.2	7.0	6.0

ATLANTIC PHASE 2 STATION 9 (43.09N, 69.63W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	9.3	10.3	8.6
20	8.1	9.3	7.8
10	7.4	8.6	7.2
5	6.8	7.9	6.6

ATLANTIC PHASE 2 STATION 10 (43.15N, 68.95W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	9.6	10.6	8.9
20	8.3	9.6	8.0
10	7.6	8.8	7.4
5	7.0	8.1	6.8

ATLANTIC PHASE 2 STATION 11 (43.29N, 66.90W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	11.7	13.1	10.7
20	9.9	11.7	9.5
10	9.0	10.7	8.7
5	8.2	9.7	7.9

ATLANTIC PHASE 2 STATION 12 (43.33N, 66.21W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	11.7	13.0	10.8
20	10.1	11.7	9.7
10	9.3	10.8	8.9
5	8.5	9.9	8.2

ATLANTIC PHASE 2 STATION 13 (42.54N, 70.23W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	8.8	9.7	8.2
20	7.7	8.8	7.4
10	7.1	8.2	6.9
5	6.6	7.6	6.4

ATLANTIC PHASE 2 STATION 14 (42.60N, 69.55W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	9.8	10.9	9.1
20	8.4	9.8	8.1
10	7.8	9.0	7.5
5	7.1	8.3	6.9

ATLANTIC PHASE 2 STATION 1 (44.24N, 67.71W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	11.2	13.0	9.9
20	8.9	11.1	8.5
10	7.9	9.9	7.5
5	7.0	8.8	6.7

ATLANTIC PHASE 2 STATION 2 (44.28N, 67.02W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	12.3	14.5	10.8
20	10.2	12.2	9.1
10	8.9	10.7	8.0
5	7.8	9.4	7.0

ATLANTIC PHASE 2 STATION 3 (44.32N, 66.32W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	9.4	10.5	8.6
20	8.0	9.4	7.7
10	7.4	8.6	7.1
5	6.7	7.9	6.5

ATLANTIC PHASE 2 STATION 4 (43.64N, 69.02W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	8.4	9.2	7.7
20	7.3	8.3	7.0
10	6.7	7.7	6.5
5	6.2	7.2	6.0

ATLANTIC PHASE 2 STATION 5 (43.69N, 68.33W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	10.3	11.7	9.3
20	8.5	10.2	8.2
10	7.7	9.3	7.4
5	6.9	8.4	6.7

ATLANTIC PHASE 2 STATION 6 (43.74N, 67.65W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	11.5	13.2	10.3
20	9.3	11.4	8.8
10	8.3	10.2	7.9
5	7.4	9.1	7.1

ATLANTIC PHASE 2 STATION 7 (43.79N, 66.96W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	12.0	13.7	10.8
20	9.9	11.9	9.4
10	8.9	10.7	8.5
5	7.9	9.7	7.6

APPENDIX A: RETURN PERIOD TABLE DERIVED FROM 20-YEAR DATA BASE

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PART IV: SUMMARY

21. The technique to estimate extreme significant wave heights discussed in this report is considered to be the most appropriate to use with the ACWIS wave data. The interquartile ranges are provided to remind the reader that there is a probability that the median 50-year (or other return period) H_s estimated may be exceeded or not reached. At some ACWIS stations the interquartile range exceeds 2m. It is important that a designer of coastal structures be aware of the range of possible extreme significant wave heights and that these wave heights have a probability of occurring in any given year (Table 2).

22. It is expected that the WIS wave data will continue to undergo revisions and additions in order to provide the most informative wave statistics to coastal workers. The changes will be published when appropriate (as in this report) and will be incorporated into the WIS Sea-State Engineering Analysis System (SEAS) for direct access by US Army Engineer Districts (Ragsdale 1983).

$$-\ln\left\{-\ln\left[(0.5)^{\frac{1}{1.85n}}\right]\right\}$$

from $100 = 1.85(54)$. The interquartile ranges for the median 100-year wave height were derived as discussed in the previous sections of this report concerning the other return period estimates. The 50-year wave height extrema were calculated also.

18. Since a storm which is severe along the North Atlantic shores may not even affect the South Atlantic coast, the storms may represent the extremes in some areas rather than in others. Therefore, an extremal analysis was performed for the ACWIS Phase II station if five of the pre-1956 storms produced an H_s greater than 5.5m. The analytical procedure combined the pre-1956 storm waves greater than 5.5m with extreme waves over 5.5m in the 20-year hindcast. The results of the extremal analyses are presented in Appendix B. These results include a median 100-year and median 50-year wave with their respective interquartile ranges.

Use of the Table

19. The 50-year extreme wave estimates in Appendix B are considered to be more appropriate than those in Appendix A due to the enlarged data base (54 years instead of 20 years). However, for several stations, waves from the pre-1956 storms did not meet the requirements noted above; for these stations the reader should use Appendix A.

Example

20. In Appendix B sta 40 shows the median 100-year H_s to be 17.6m and an interquartile range of 15.2m to 21.2m (see page B5). Using Table 2 it can be seen that there is a probability of 0.01 for a wave equal to or greater than 17.6m to occur at sta 40 in any one year. Table 2 also shows that there is a 0.64 probability for a wave equal to or greater than 17.6m to occur in 100 years.

PART III: RETURN PERIOD TABLE DERIVED FROM THE 54-YEAR DATA BASE

Description

15. In addition to the extremal analyses of the 20 years of Phase II wave heights, extremal analyses of wave heights for storms prior to 1956 were performed. The storms prior to 1956 selected for analysis were chosen to represent the most severe storms for the US Atlantic Coast. The dates of the extra-tropical storms (pre-1956) selected are:

a. 27-31 January 1922.
b. 9-13 March 1924.
c. 2-6 March 1931.
d. 26-29 November 1932.
e. 25-29 January 1933.
f. 28 November-2 December 1945.
g. 20-22 February 1947.
h. 31 January-2 February 1948.
i. 24-27 November 1950.
j. 6-9 January 1952.
k. 26-29 February 1952.
l. 5-8 November 1953.

Hindcast wave data for the storms were derived using the WIS numerical wave model which uses wind fields for input (Resio and Tracy 1983). The wind field data for the storms were reconstructed under contract by Oceanweather, Inc., under the direction of Dr. V. Cardone.

16. By hindcasting the storms prior to 1956 the Phase II data base has been extended from 20 years to 54 years. Assuming that the listed 12 storms between 1922 and 1955 represent the storms of record for this period, this 54-year data base can be used to extrapolate to a wave height associated with the 100-year return period using the procedures discussed in previous sections of this report. It must be assumed also that the storms occurring from 1922 to 1955 represent a population of storms similar to the most severe storms represented in the WIS 1956-1975 hindcast.

17. Since the input data set encompasses 54 years, the median 100-year wave height was calculated using the abscissa function

lower limit of wave period T_L is given in Isaacson and MacKenzie (1981) as

$$T_L = \sqrt{10.25*H_s} \tag{15}$$

where the period is assumed to be limited by a characteristic wave steepness of 0.0625, i.e., 1/16. Since the ACWIS Phase II wave data represent deepwater conditions, it is possible for the extrapolated H_s to occur from any direction. However, as a conservative approach the reader may wish to assume that the extrapolated H_s will be traveling from the open-ocean toward the coast.

Example

14. In Appendix A the median 50-year H_s for sta 1 is 11.2m, and the interquartile range is from 9.9m to 13.0m (see page A2). Using Table 2 it can be seen that the median 50-year H_s or a larger H_s has a probability of 0.02 of occurring in any one year.

0.25 and 0.75 probability of the 20- and 50-year median wave heights. For example, these ranges indicate that 75 percent of the 50-year wave heights should (based on the assumed probability distribution function) fall at or below the 0.75 quartile of the 50-year wave height. It is also possible that a wave height can occur outside of these ranges.

Use of the Table

12. Appendix A contains the return period tables calculated from the data in the 20-year hindcast. These tables contain the medians of the 50-, 20-, 10-, and 5-year wave heights, and it is expected that these medians and their respective interquartile ranges will be used for estimates of extremes for design applications. The 0.25 and 0.75 fractiles are provided to indicate the possible variation in the extreme estimates. It should be noted that there is a probability of extreme wave heights occurring in any year. Table 2 indicates the probabilities associated with the wave heights of the various return periods for selected time intervals. Thus the reader is allowed to take a wave height associated with a return period and find the probability that this wave height or a larger wave height will occur in 1, 10, 25, 50, or 100 years.

13. It is difficult to represent the wave period and direction that will be associated with the extrapolated wave heights. One means of estimating a

Table 2

Probabilities of Extreme Wave Heights*

Return Period	Probability of Getting One or More Storms with Return Period Waves or Bigger Waves in this Many Years				
Years	1	10	25	50	100
5	0.20	0.89	>0.99	>0.99	>0.99
10	0.10	0.65	0.93	>0.99	>0.99
20	0.05	0.40	0.72	0.92	>0.99
50	0.02	0.18	0.40	0.64	0.87
100	0.01	0.10	0.22	0.39	0.63

* From Reich (1973).

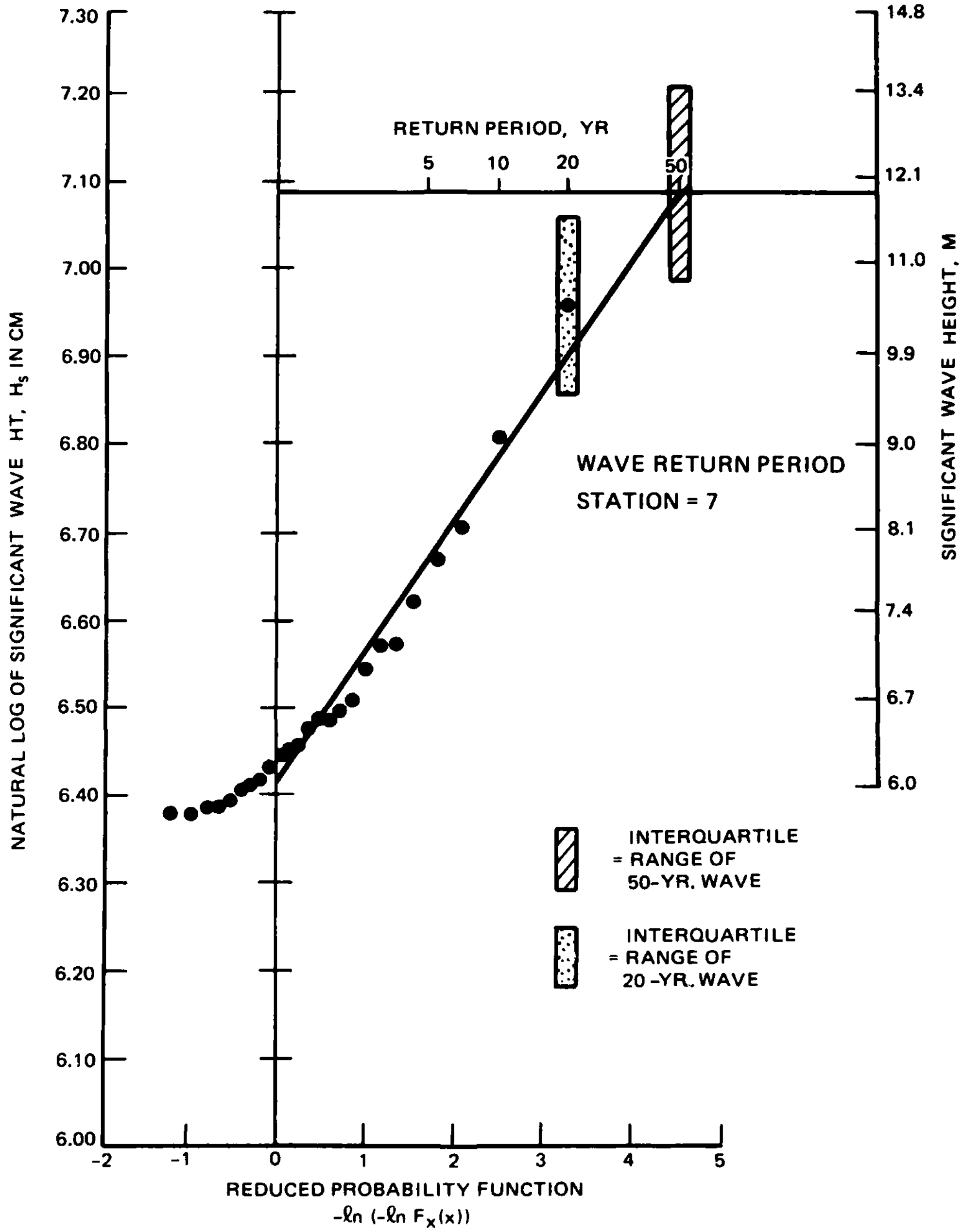

Figure 2. Representative graph of ln of H_s as a function of the reduced probability function. (A scale also is given for H_s and the return period. The interquartile ranges are shown for the 50-year and 20-year waves.)

ATLANTIC PHASE 2 STATION 43 (34.38N, 76.45W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	8.2	8.8	7.8
20	7.5	8.2	7.2
10	7.1	7.7	6.8
5	6.7	7.3	6.4

ATLANTIC PHASE 2 STATION 44 (34.46N, 75.85W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	9.7	10.7	9.0
20	8.7	9.7	8.2
10	8.1	9.0	7.6
5	7.5	8.4	7.1

ATLANTIC PHASE 2 STATION 45 (34.54N, 75.25W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	11.8	13.4	10.7
20	10.1	11.7	9.3
10	9.1	10.6	8.4
5	8.2	9.6	7.6

ATLANTIC PHASE 2 STATION 46 (33.55N, 78.72W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	6.7	7.2	6.3
20	6.1	6.7	5.9
10	5.7	6.3	5.5
5	5.4	6.0	5.2

ATLANTIC PHASE 2 STATION 47 (33.64N, 78.13W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.6	8.2	7.2
20	6.9	7.6	6.6
10	6.5	7.1	6.3
5	6.1	6.7	5.9

ATLANTIC PHASE 2 STATION 48 (33.73N, 77.54W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	8.6	9.4	8.0
20	7.8	8.6	7.3
10	7.3	8.0	6.8
5	6.8	7.4	6.3

ATLANTIC PHASE 2 STATION 49 (33.08N, 78.62W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.4	8.0	6.9
20	6.9	7.4	6.4
10	6.5	6.9	6.0
5	6.1	6.5	5.7

ATLANTIC PHASE 2 STATION 50 (32.33N, 80.26W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	6.0	6.4	5.7
20	5.6	6.0	5.3
10	5.3	5.7	5.1
5	5.0	5.4	4.8

ATLANTIC PHASE 2 STATION 51 (32.42N, 79.68W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.7	8.4	7.1
20	6.9	7.6	6.4
10	6.4	7.1	6.0
5	5.9	6.6	5.6

ATLANTIC PHASE 2 STATION 52 (32.51N, 79.10W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	8.0	8.7	7.5
20	7.3	7.9	6.9
10	6.8	7.4	6.4
5	6.4	7.0	6.0

ATLANTIC PHASE 2 STATION 53 (32.60N, 78.51W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	8.2	8.9	7.7
20	7.4	8.2	7.2
10	7.0	7.7	6.7
5	6.6	7.3	6.3

ATLANTIC PHASE 2 STATION 54 (31.86N, 80.15W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.3	7.9	6.9
20	6.7	7.3	6.3
10	6.3	6.8	5.9
5	5.9	6.4	5.6

ATLANTIC PHASE 2 STATION 55 (31.29N, 80.62W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.8	8.7	7.2
20	6.9	7.8	6.5
10	6.3	7.2	5.9
5	5.8	6.6	5.5

ATLANTIC PHASE 2 STATION 56 (31.39N, 80.01W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.9	8.6	7.4
20	7.0	7.9	6.8
10	6.5	7.4	6.3
5	6.1	6.9	5.9

ATLANTIC PHASE 2 STATION 57 (30.73N, 81.08W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	5.6	6.0	5.3
20	5.1	5.6	5.0
10	4.9	5.3	4.8
5	4.6	5.1	4.5

ATLANTIC PHASE 2 STATION 58 (30.82N, 80.51W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.9	8.7	7.3
20	6.9	7.9	6.6
10	6.4	7.3	6.2
5	5.9	6.8	5.7

ATLANTIC PHASE 2 STATION 59 (30.26N, 80.98W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.0	7.5	6.6
20	6.3	6.9	6.1
10	5.9	6.5	5.7
5	5.5	6.2	5.4

ATLANTIC PHASE 2 STATION 60 (29.79N, 80.88W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.5	8.1	7.1
20	6.8	7.5	6.6
10	6.4	7.1	6.2
5	6.0	6.7	5.9

ATLANTIC PHASE 2 STATION 61 (29.89N, 80.31W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.7	8.2	7.3
20	7.0	7.7	6.8
10	6.6	7.3	6.5
5	6.3	6.9	6.1

ATLANTIC PHASE 2 STATION 62 (29.42N, 80.21W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.9	8.4	7.5
20	7.2	7.9	7.0
10	6.8	7.5	6.7
5	6.5	7.1	6.3

ATLANTIC PHASE 2 STATION 63 (28.95N, 80.11W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.3	7.8	6.9
20	6.6	7.3	6.4
10	6.2	6.8	6.0
5	5.8	6.5	5.6

ATLANTIC PHASE 2 STATION 64 (28.48N, 80.02W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.4	8.1	6.9
20	6.5	7.4	6.3
10	6.1	6.9	5.9
5	5.6	6.4	5.5

ATLANTIC PHASE 2 STATION 65 (28.01N, 79.93W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.5	8.2	7.0
20	6.6	7.5	6.4
10	6.1	7.0	6.0
5	5.7	6.5	5.6

ATLANTIC PHASE 2 STATION 66 (27.54N, 79.84W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	6.6	7.1	6.2
20	5.9	6.6	5.7
10	5.5	6.2	5.3
5	5.2	5.8	5.0

ATLANTIC PHASE 2 STATION 67 (27.07N, 79.75W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.7	8.5	7.0
20	6.6	7.6	6.3
10	6.0	7.0	5.8
5	5.5	6.4	5.3

ATLANTIC PHASE 2 STATION 68 (27.15N, 79.20W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	8.6	9.6	7.9
20	7.4	8.6	7.1
10	6.8	7.9	6.5
5	6.2	7.2	6.0

ATLANTIC PHASE 2 STATION 69 (27.23N, 78.64W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	8.5	9.3	7.8
20	7.3	8.4	7.1
10	6.8	7.8	6.6
5	6.2	7.2	6.1

ATLANTIC PHASE 2 STATION 70 (26.60N, 79.67W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	7.7	8.6	7.1
20	6.6	7.7	6.3
10	6.1	7.1	5.8
5	5.5	6.5	5.3

ATLANTIC PHASE 2 STATION 71 (26.13N, 79.58W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	8.5	9.3	7.8
20	7.3	8.4	7.1
10	6.8	7.8	6.6
5	6.2	7.2	6.1

ATLANTIC PHASE 2 STATION 72 (26.20N, 79.03W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	6.6	8.1	5.7
20	6.4	6.6	4.6
10	5.4	5.6	3.9
5	4.4	4.8	3.4

ATLANTIC PHASE 2 STATION 73 (25.66N, 79.50W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
50	6.8	7.6	6.3
20	5.9	6.8	5.7
10	5.5	6.3	5.3
5	5.0	5.8	4.9

APPENDIX B: RETURN PERIOD TABLE DERIVED FROM 54-YEAR DATA BASE

ATLANTIC PHASE 2 STATION 3 (44.32N, 66.32W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	10.9	12.6	9.7
50	9.0	11.4	8.7

ATLANTIC PHASE 2 STATION 14 (42.60N, 69.55W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	10.5	12.0	9.5
50	9.2	10.9	8.6

ATLANTIC PHASE 2 STATION 15 (42.83N, 66.16W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	12.3	13.9	11.2
50	11.0	12.8	10.3

ATLANTIC PHASE 2 STATION 16 (42.11N, 69.48W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	10.4	11.5	9.6
50	9.4	10.7	8.9

ATLANTIC PHASE 2 STATION 17 (41.61N, 69.40W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	11.8	13.2	10.7
50	10.5	12.2	9.9

ATLANTIC PHASE 2 STATION 18 (40.88N, 71.96W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	10.8	12.2	9.8
50	9.6	11.2	9.0

ATLANTIC PHASE 2 STATION 19 (40.94N, 71.30W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	13.3	15.4	11.8
50	11.5	13.9	10.7

ATLANTIC PHASE 2 STATION 20 (41.01N, 70.65W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	12.5	14.2	11.3
50	10.7	13.0	10.3

ATLANTIC PHASE 2 STATION 21 (41.06N, 69.99W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	13.5	15.5	12.1
50	11.4	14.1	11.0

ATLANTIC PHASE 2 STATION 22 (42.12N, 69.33W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	13.2	14.9	12.0
50	11.4	13.7	11.0

ATLANTIC PHASE 2 STATION 23 (40.17N, 73.82W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	16.2	19.9	13.8
50	12.5	17.2	11.9

ATLANTIC PHASE 2 STATION 24 (40.24N, 73.17W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	17.3	21.7	14.4
50	13.0	18.5	12.3

ATLANTIC PHASE 2 STATION 25 (40.32N, 72.52W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	16.4	20.0	14.1
50	12.9	17.4	12.3

ATLANTIC PHASE 2 STATION 26 (40.39N, 71.87W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	14.7	17.2	13.0
50	12.1	15.4	11.6

ATLANTIC PHASE 2 STATION 27 (39.68N, 73.72W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	19.1	24.3	15.8
50	14.2	20.6	13.3

ATLANTIC PHASE 2 STATION 28 (39.12N, 74.26W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	20.3	26.1	16.7
50	14.8	21.9	14.0

ATLANTIC PHASE 2 STATION 29 (39.20N, 73.62W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	16.7	20.2	14.4
50	13.3	17.7	12.6

ATLANTIC PHASE 2 STATION 30 (38.55N, 74.79W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	23.5	31.5	18.6
50	16.2	25.7	15.1

ATLANTIC PHASE 2 STATION 31 (38.63N, 74.16W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	27.1	38.2	20.7
50	17.8	30.1	16.3

ATLANTIC PHASE 2 STATION 32 (38.07N, 74.69W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	20.7	26.2	17.2
50	15.4	22.2	14.6

ATLANTIC PHASE 2 STATION 33 (37.51N, 75.21W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	19.8	24.7	16.6
50	14.9	21.1	14.2

ATLANTIC PHASE 2 STATION 34 (37.59N, 74.59W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	16.2	18.7	14.5
50	13.6	17.0	13.1

ATLANTIC PHASE 2 STATION 35 (37.03N, 75.11W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	19.4	23.6	16.7
50	15.3	20.6	14.6

ATLANTIC PHASE 2 STATION 36 (36.54N, 75.02W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	23.3	30.3	18.9
50	16.8	25.2	15.7

ATLANTIC PHASE 2 STATION 37 (36.06N, 74.92W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	19.4	23.9	16.5
50	15.0	20.7	14.2

ATLANTIC PHASE 2 STATION 38 (35.58N, 74.83W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	18.7	22.8	16.0
50	14.7	19.9	14.0

ATLANTIC PHASE 2 STATION 39 (35.02N, 75.34W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	18.3	22.1	15.8
50	14.6	19.4	13.9

ATLANTIC PHASE 2 STATION 40 (35.09N, 74.74W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	17.6	21.2	15.2
50	14.0	18.6	13.3

ATLANTIC PHASE 2 STATION 41 (34.12N, 77.64W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	15.3	17.7	13.6
50	12.7	16.0	12.3

ATLANTIC PHASE 2 STATION 42 (34.29N, 77.04W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	18.8	23.4	15.8
50	14.4	20.1	13.6

ATLANTIC PHASE 2 STATION 43 (34.38N, 76.45W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	16.3	19.3	14.2
50	13.2	17.1	12.6

ATLANTIC PHASE 2 STATION 44 (34.46N, 75.85W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	15.8	18.7	13.8
50	12.8	16.6	12.3

ATLANTIC PHASE 2 STATION 45 (34.54N, 75.25W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	16.6	19.8	14.4
50	13.4	17.5	12.7

ATLANTIC PHASE 2 STATION 46 (33.55N, 78.72W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	14.5	16.3	13.2
50	12.5	15.0	12.2

ATLANTIC PHASE 2 STATION 47 (33.64N, 78.13W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	16.4	19.4	14.3
50	13.3	17.2	12.7

ATLANTIC PHASE 2 STATION 48 (33.73N, 77.54W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	15.4	17.7	13.8
50	13.0	16.0	12.5

ATLANTIC PHASE 2 STATION 49 (33.08N, 78.62W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	15.1	17.1	13.6
50	12.8	15.7	12.4

ATLANTIC PHASE 2 STATION 50 (32.33N, 80.26W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	12.0	12.7	11.5
50	11.6	12.2	11.1

ATLANTIC PHASE 2 STATION 51 (32.42N, 79.68W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	12.4	13.4	11.7
50	11.3	12.7	11.1

ATLANTIC PHASE 2 STATION 52 (32.51N, 79.10W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	15.0	17.9	13.0
50	12.1	15.8	11.5

ATLANTIC PHASE 2 STATION 53 (32.60N, 78.51W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	13.2	15.2	11.8
50	11.2	13.8	10.7

ATLANTIC PHASE 2 STATION 54 (31.86N, 80.15W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	11.5	12.7	10.6
50	10.2	11.8	9.9

ATLANTIC PHASE 2 STATION 55 (31.29N, 80.62W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	13.6	16.1	12.0
50	11.2	14.3	10.7

ATLANTIC PHASE 2 STATION 56 (31.39N, 80.01W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	13.8	16.4	12.0
50	11.1	14.5	10.6

ATLANTIC PHASE 2 STATION 57 (30.73N, 81.08W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	11.2	12.8	10.1
50	9.8	11.7	9.2

ATLANTIC PHASE 2 STATION 58 (30.82N, 80.51W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	12.3	14.5	10.8
50	10.1	12.9	9.6

ATLANTIC PHASE 2 STATION 59 (30.26N, 80.98W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	10.9	12.6	9.8
50	9.3	11.4	8.9

ATLANTIC PHASE 2 STATION 60 (29.79N, 80.88W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	10.9	12.4	9.8
50	9.2	11.3	9.0

ATLANTIC PHASE 2 STATION 61 (29.89N, 80.31W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	10.7	12.2	9.7
50	9.2	11.1	8.9

ATLANTIC PHASE 2 STATION 62 (29.42N, 80.21W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	10.5	11.9	9.5
50	9.0	10.9	8.7

ATLANTIC PHASE 2 STATION 63 (28.95N, 80.11W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	12.1	14.5	10.5
50	9.6	12.8	9.3

ATLANTIC PHASE 2 STATION 64 (28.48N, 80.02W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	11.5	13.7	10.0
50	9.2	12.1	8.9

ATLANTIC PHASE 2 STATION 65 (28.01N, 79.93W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	11.4	13.3	10.0
50	9.3	11.9	9.0

ATLANTIC PHASE 2 STATION 66 (27.54N, 79.84W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	11.2	12.9	10.1
50	9.9	11.7	9.1

ATLANTIC PHASE 2 STATION 67 (27.07N, 79.75W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	10.2	11.5	9.2
50	8.6	10.6	8.5

ATLANTIC PHASE 2 STATION 68 (27.15N, 79.20W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	9.2	10.0	8.6
50	8.2	9.4	8.0

ATLANTIC PHASE 2 STATION 69 (27.23N, 78.64W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	9.4	10.5	8.7
50	8.3	9.7	8.1

ATLANTIC PHASE 2 STATION 70 (26.60N, 79.67W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	8.4	9.2	7.9
50	7.5	8.6	7.4

ATLANTIC PHASE 2 STATION 71 (26.13N, 79.58W)

RETURN PERIOD (YRS)	HS(M)	UPPER LIMIT HS(M) ASSOCIATED WITH .75 FRACTILE	LOWER LIMIT HS(M) ASSOCIATED WITH .25 FRACTILE
100	10.3	12.3	9.0
50	8.6	10.9	7.9

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